STUDY AND REPORT

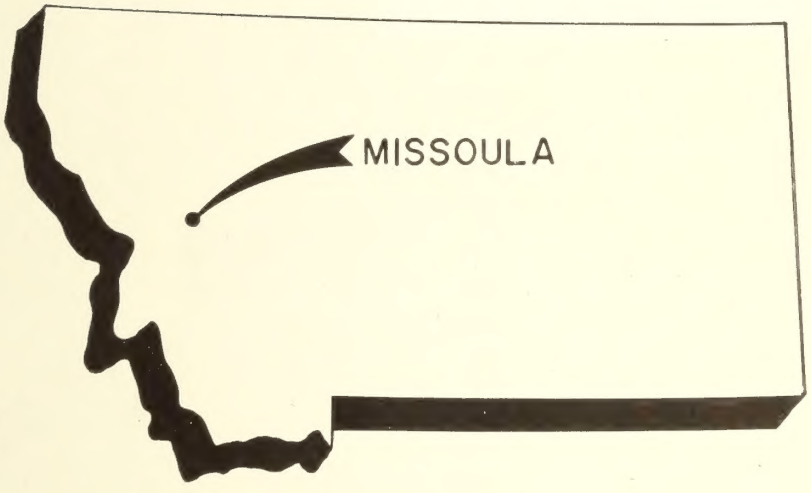
FOR

MISSOULA URBAN DRAINAGE

INTERSTATE HIGHWAY

PROJECT I-90-2(27)103 UNIT I

MISSOULA, MONTANA



PROJECT
NUMBER
275-18-01

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NUMBER
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MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS
HELENA — BILLINGS
MONTANA

INVESTIGATION REPORT

MISSOULA URBAN DRAINAGE

NEAR

MISSOULA, MONTANA

MONTANA INTERSTATE HIGHWAY PROJECT

NO. I 90-2 (27) 103, UNIT 1

Prepared By
MORRISON-MAIERLE, INC.
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July 1, 1967

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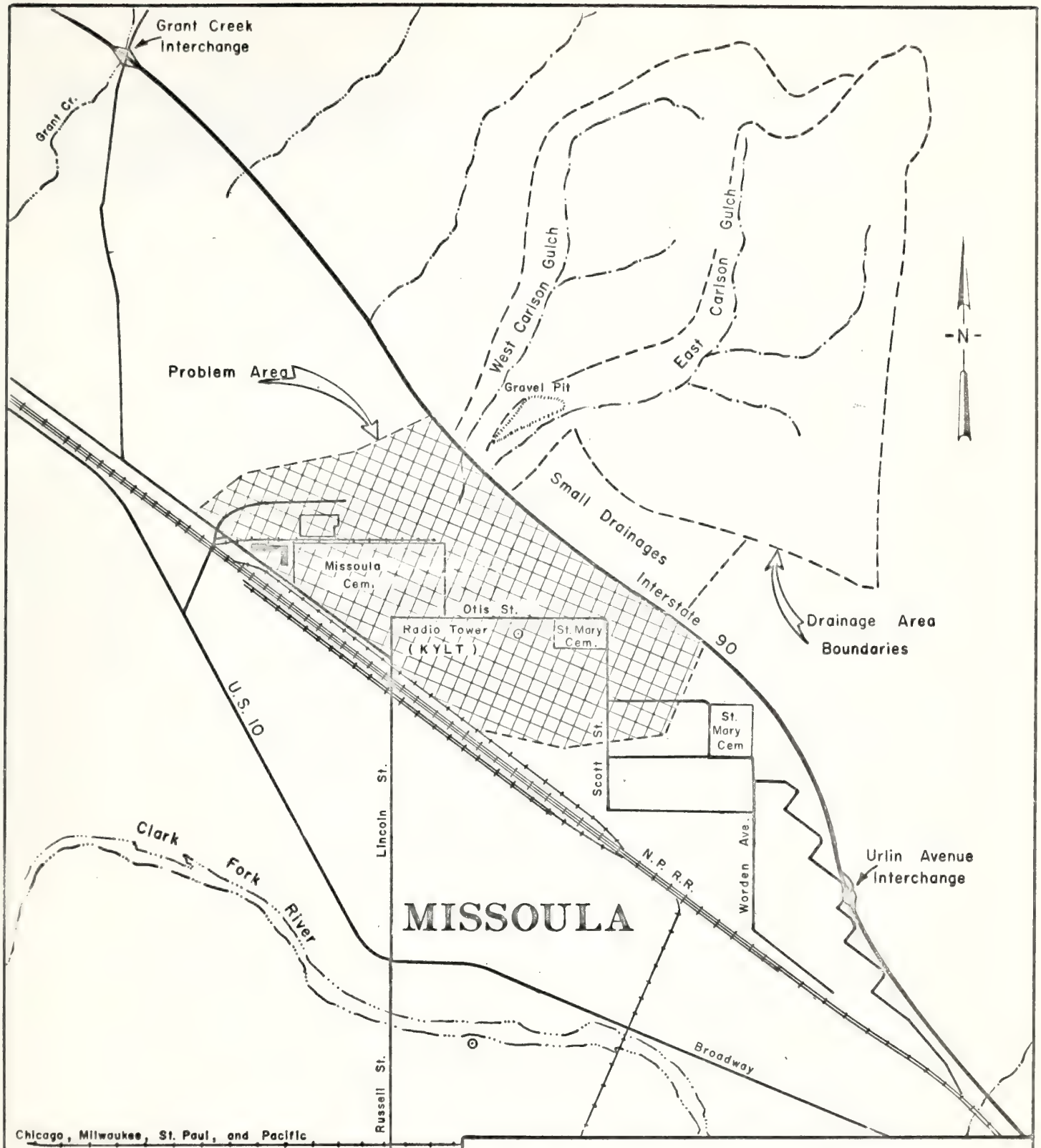
INTRODUCTION

Interstate Highway 90, through and adjacent to the northwest part of Missoula, Montana, crosses a number of ravines or gulches which intermittently discharge surface water toward a growing industrial and residential area and cemeteries. The Montana Highway Commission engaged the firm of Morrison-Maierle, Inc., Consulting Engineers of Helena, Montana on March 24, 1967 to make a detailed study of drainage conditions in this area. This study was to be directed to the determination of drainage conditions prior and subsequent to the construction of Interstate Highway 90, and to make recommendation for the correction of adverse effects introduced by that project.

The LOCATION MAP, FIGURE 1 may serve for orientation and general description. The cross-hatched area, labelled problem area lies between the Interstate Highway and the Northern Pacific Railway. It is principally within Sec. 9 T13N, R19W. The related drainage areas north of the Interstate Highway are outlined. The discharge of these drainage areas passes under the Interstate in a series of culverts. Through the ages these feeder streams built up debris cones or fans as they reached the problem area. The intermittent nature of their flows did not lend itself to the formation of well entrenched stream channels. There is a poorly formed trough with a general northwest trend near the middle of the problem area, which may mark the course of a former river channel. There are a number of depressions or pot holes, some of which have been changed by the construction of streets, roads and other improvements. The movement of water to these depressions and westward has thus been altered. The soils in the problem area contain varying amounts of clay, silt and gravels. The drilling logs of water wells in the area and well yields show a highly permeable aquifer with a general water gradient along the lines of the trough. The ability of this aquifer to carry off water has probably hindered the natural development of stream channels. The U.S. Geological Survey topographic map, northwest Missoula prepared on the basis of photography of 1961 and field checks of 1963, show a channel from Grant Creek leading toward the Northern Pacific Railway in the $SW\frac{1}{4}$, Sec. 8. It is understood there was provision for passing this water or other water beneath the railroad. The rare need for the railroad culvert and the growing industrial development beyond may have prompted the closure of the culvert when the Northern Pacific Railroad constructed wider trackage a few years ago.

The volume of surface water reaching the problem area is reported to be much greater during winter snow melt such as occurred on March 10, 11, 1966, shortly after the Interstate Highway was completed. Some old residents of the general area report that there have also been high flows and ponding as the result of high intensity rains.

The various factors affecting runoff and its direction of travel were investigated in an impartial way to determine the effect of Interstate



MISSOULA URBAN DRAINAGE

MISSOULA, MONTANA

LOCATION MAP

Drawn	PROJECT 275-18-01
Checked	MORRISON-MAIERLE, INC.
Approved	CONSULTING ENGINEERS
Date	HELENA, MONTANA

FIGURE 1

Highway 90 upon the long-standing drainage problem of this area or parts thereof. The disposal of the objectionable water was studied to the extent of reasonable methods of lessening the problem. There appears to be no reasonable means of providing full protection from rare hydrologic events.

PART 1

INVESTIGATIONS

1.01 GENERAL:

To develop the situation prior to the construction of the Interstate Highway, various maps, and photographs were examined. Field surveys and inquiries played a minor part in reconstructing that status. A map, P1 was prepared to show the general features. The Interstate Highway and revised frontage roads at Carlson Gulch were superimposed upon this map which also serves as a key map to the enlarged mapping and greater detail of the maps P-2 to P-6. The situation following the construction of the highway was developed by sufficient field surveys to verify data available in the files of the Montana Highway Commission and to obtain new data where needed. The maps P-7 to P-11 cover the same areas as maps P-2 to P-6. In addition to the above two groups of maps, additional maps or sketches were prepared as considered necessary to illustrate various facets.

The hydrology of the area was studied on the basis of weather data and runoff criteria and inquiry of old residents. Newspaper files were examined in considerable detail without significant success. Geological reconnaissance served to aid judgement factors of runoff criteria. A number of test holes were drilled to test the percolation rate of water to the subsoils and lower depths. Infiltration tests were made to observe the rates of water penetration through the topsoil.

The approximate extent to which Interstate Highway construction affected drainage problems was considered the guideline for investigations of the disposal of excess surface water. The former gravel pit area north of the Interstate Highway was mapped in sufficient detail to arrive at the potential in that area. Other areas were viewed and examined on the basis of maps or other information.

1.02 INFILTRATION:

Infiltration tests were made by imbedding a sharp-edged can with a diameter of 5 inches about 2 inches into the soil and tamping around the outer rim to minimize other than generally vertical water movement. Water was poured into the holes to a depth of about 2 inches and the rate of water drop was determined. If water loss was rapid, a second test was made immediately following the first at the same location at most sites. A parallel test was generally conducted at each general location. It is realized that the head or pressure forcing water into the soil under natural conditions would generally be less than 1/4-inch. Higher heads would develop in channels and ponded areas. The information obtained would have little value in interpreting the minor infiltration during the snow-melt conditions when the ground is frozen.

Ordinarily infiltration tests are made by simulated rain application of water over a large enough area to practically eliminate the effect of lateral seepage. Infiltration under these conditions may be as little as a few hundreths of an inch per hour to perhaps 3 inches per hour for highly porous soils. The results obtained in the tests of this study are substantially higher than could be expected for the absorption of rain water or the leakage from ponds. The location of the numbered tests are shown on Map P-1, and results given in TABLE 1.

TABLE 1 - INFILTRATION TEST RESULTS

Location No.	Average Infiltration (Inches per Hour)	Location No.	Average Infiltration (Inches per Hour)
1A	16	7	e) 4.0
1B	4.5	7	9
1	a)	8	11
2	5.8	9	f) 56
3	1.5	10	18
4	1.7	11	4.5
5	b) 2.7	12	a)
5	c) 24	13	a)
6	2		
6	d) 34		

a) No test made. Water from recent rains or runoff standing in pools.
b) In ditch bottom.
c) In soil with bark and chips from log yard.
d) In sandy bottom of drainage ditch.
e) Area travelled by some logging trucks.
f) Dense cover of tall grass.

1.03 PERCOLATION:

After the upper soil is soaked to its field capacity to retain water, percolation to deeper soils will occur. The field capacity of soils may vary from 5 percent for sand to about 35 percent for clay. If the lower soils are permeable the water will move in a downward and outward direction. Available information on groundwater wells indicates a general southwesterly gradient of the water table which lies about 40 to 50 feet below the ground surface. There appears to be a groundwater gradient along the alluvial fan of Grant Creek in the northwest part of Section 8. Drilling for the Carlson Gulch underpass did not encounter a groundwater table at depths of 70 feet or elevations of about 3150 feet. There is every indication that there is space for the storage of the surface flow of Carlson Gulch beneath the ground without causing any disturbing temporary rise in the groundwater table in the area affected by periodic flooding.

Percolation tests were conducted by observing the rate at which water would sink into 13 augered holes varying in depth from 18½ feet to about 4 feet. An 8-inch earth auger was used for drilling. In many locations the effective diameter of the hole was about 12 inches due to the removal of coarse gravel or sloughing. The soils were damp, but no free water was encountered. The 13 locations are shown on the map Pl. The initial water fill preceded the percolation observations by 4 to 24 hours. Because of lateral seepage, the percolation rates observed in the tests should not be interpreted as the amount of percolation that could be expected when water is applied to a large area. The results are given in TABLE 2. Percolation rates are adequate for underground disposal of water in much of the area. There could be very little percolation in most of the Van-Evan log yard and along the frontage road to the east. The clays at location No. 1 permit no appreciable percolation. The nearby channel of location No. 2 is highly permeable indicating a coarse alluvial fill of considerable depth.

TABLE 2 - PERCOLATION TESTS

No.	Description	Ground Elev. Ft.	Depth of Hole Ft.	Dist. To Water Fill Ft.	Percolation	Rate in ft. Per Hr.
1	On graded berm of gravel pit. Yellowish clay and gravel for 6 ft., grading to highly plastic gray clay fairly free of grit.	3265.1	18.5	13.8	0.7 ft. in 54 hrs	.01
2	In E. Carlson Gulch about 20 feet from shallow channels, 3 inches of grassy topsoil over gravels with some yellow clays.	3243.6	8.5	1.3	7 ft. + in less than 2 hrs	3.5 +
				7.1	0.3 ft. in 5 min.	3.6
3	In ditch along frontage road. Fairly uniform mixture of fine gravel, sand and yellowish clay.	3217.8	7	a) 2	Found dry in 17½ hrs.	
				3.3	2.3 ft. in 6.7 hrs	0.34
4	200 ft. south of culvert outlet of W.Carlson Gulch. 8 inches black topsoil above fine gravel and sand in mixture of light and dark soils.	3215.6	3.7	1.1	2.2 ft. in 1½ hrs	1.5
				0.5	Found dry in 4½ hrs	

Table 2 - Percolation Tests - Continued

No.	Description	Ground Elev. Ft.	Depth Of Hole Ft.	Dist. To Water Fill Ft.	Percolation	Rate In ft. Per Hr.
5	In ditch on SW side of frontage road. Clay and coarse gravel under 3 inches of bark waste from plywood mill	3201.4	5.5	0.42	2.8 ft. in $8\frac{1}{2}$ Hrs.	0.33
6	Near ditch on SW side of frontage road. 3 inches of densely turfed top soil over clay and coarse gravel with little sand.	3192.8	3.5	0.63	1.0 ft. in 50 Hrs.	0.02
7	About 200 ft. W of Shakespeare St. and 400 ft. N of Otis St. about 6 inches dark topsoil over gravelly sand with a small amount of clay.	3186.7	2.5	0.5	Dry in $\frac{1}{2}$ hr.	4.0
				0.5	0.62 in 25 min.	1.5
8	About 50 ft. NE of corner of Shakespeare and Otis Sts. 3 inches dark soil over med. gravel & sand with some clay.	3185.9	2.8	0.18	1.4 ft. in $3\frac{1}{4}$ Hrs.	0.4
9	W. side of Scott St. about 100 ft. N. of Clark St. 6 inches of loamy black soil, grading to gravels with more clay with depth.	3188.3	5	0.17	3.0 ft. in 4 hrs	0.75
10	N side of Otis St. about 500 ft. W. of Shakespeare. 3 inches topsoil over fine gravel & sand with very little clay.	3188.8	5	0.38	2.8 ft. in 4+ hrs	0.7

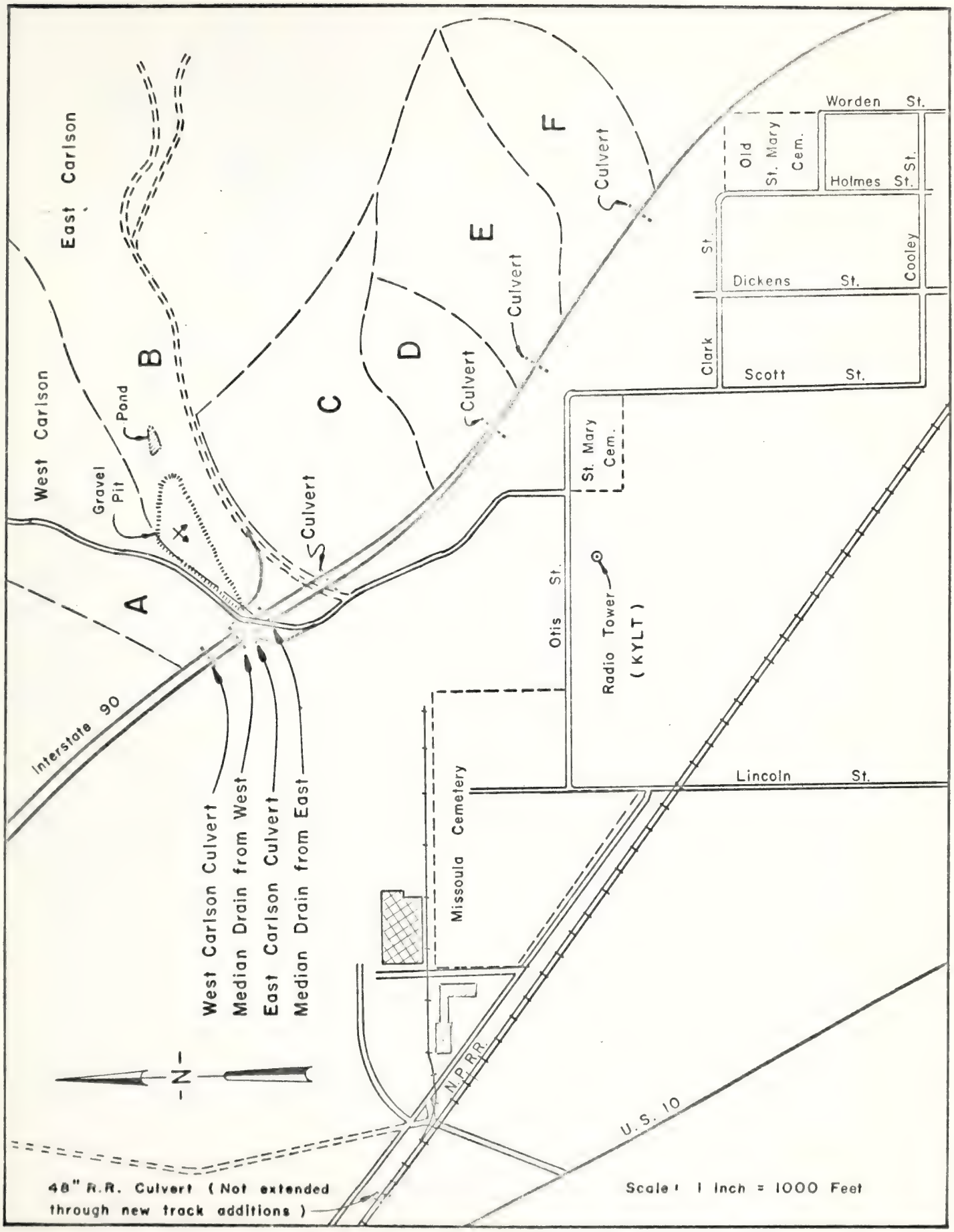
Table 2 - Percolation Tests - Continued

No.	Description	Ground Elev.	Depth Of Hole	Dist. To Water Fill	Percolation	Rate In Ft. Per Hr.
11	N side of Otis St. about 1400 ft. W. of Shakespeare St. Gravel & clay soil for about 4 ft. may be fill over darker loamy clay soil.	3184.2	6.8	3.33	1.9 ft. in $4\frac{1}{4}$ hrs.	0.45
12	About 400 ft. W. of frontage road and in Van-Evan log yard. Heavy wet clay with some gravel. More gravelly in last 2 ft.	3192.7	7.5	1.0	Top 4 ft. in 19 hrs.	0.21
				5.08	0.16 ft. in 22 + hrs.	0.01
13	About 700 ft. W. of frontage road along north side of Van-Evan log yard. About 1 ft. clay-gravel fill over gray silt-clay. Yard level cut about 3 ft. below natural ground.	3190.6	6.7	0.0	3.2 ft. in $41\frac{1}{2}$ hrs.	0.08

a) Initial soak.

1.04 SURFACE WATER DRAINAGE AREAS:

The principal drainage areas affecting runoff into the area are shown on the LOCATION MAP, FIGURE 1. The scale of the DRAINAGE SKETCH, FIGURE 2 permits identification of culvert locations and subdivision of the smaller drainages that cross the Interstate in the general area. A listing of the drainages served by present culverts other than median drains is given for early identification and subsequent reference.



DRAINAGE SKETCH

FIGURE 2

Area Symbol	Stream or Area	Drainage Area in Acres above Interstate Highway
A	West Carlson Gulch	315
B	East Carlson Gulch	500
C	Sidehill drainage near Frontage Roads	64
D	Sidehill drainage	28
E	Sidehill drainage	50
F	Sidehill drainage	40

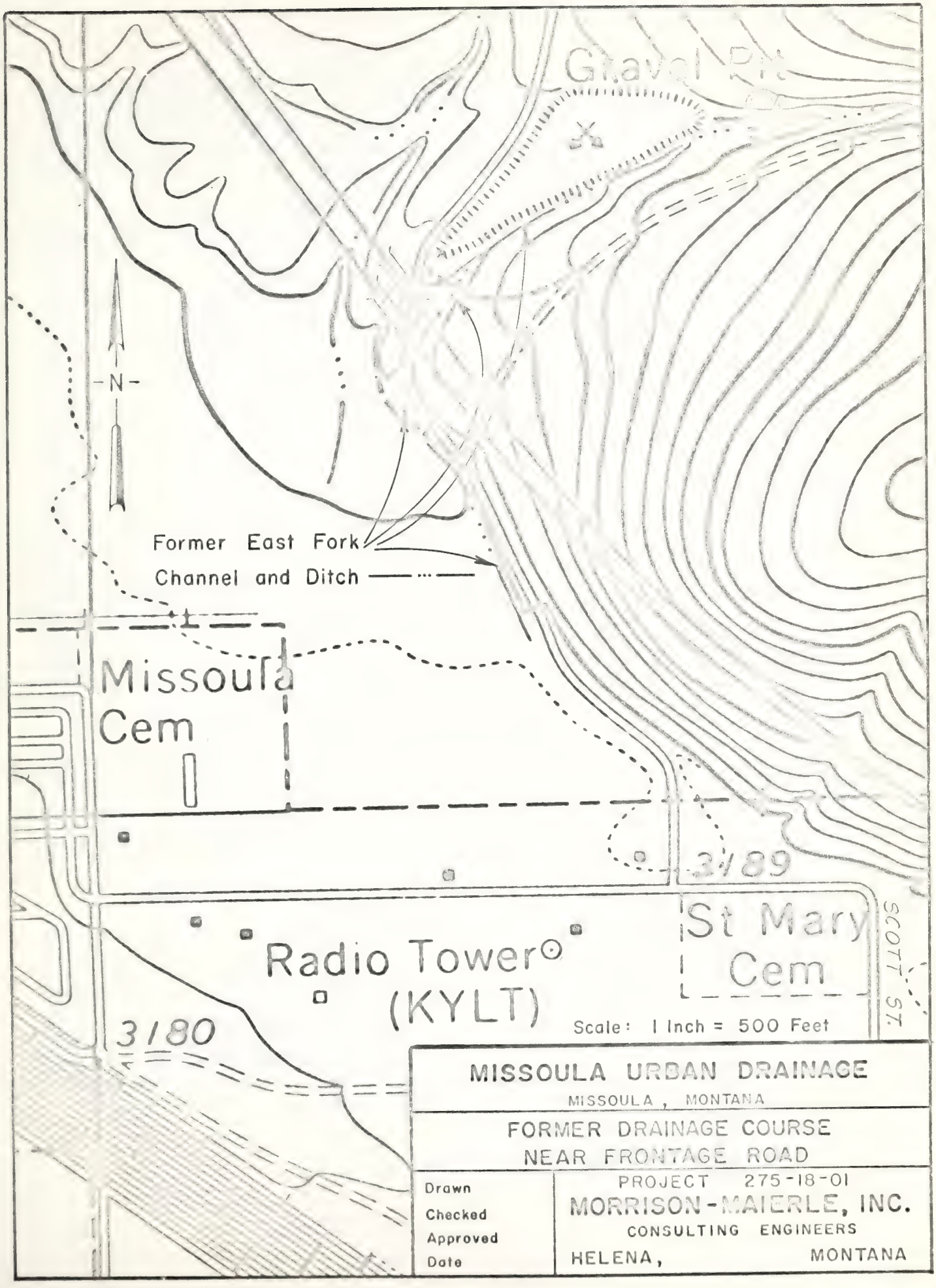
The maps P-2 to P-11 on a scale of 1 inch equals 100 feet will assist in providing details of topography.

AREA A - West Carlson Gulch

The drainage course and probable volume of flow were only slightly altered by the construction of the Interstate Highway. The drainage area is about 315 acres. The culvert entrance is in the natural channel and the direction of discharge is very nearly the same. The culvert no longer carries the flow of an irrigation ditch from Grant Creek. It is reasonable to assume that some sidehill drainage or Grant Creek water was carried by this ditch during some flood periods. The culvert discharges on an alluvial fan and the slope of the ground beyond indicates the water would spread out over the cultivated land. Water which did not percolate into the soil would reach the Van-Evan property at points about 300 to 600 feet west of the Frontage Road. From there it could follow a small ditch westward or spread out over the log yard. Some water could pass further southward to reach the ponding area near Shakespeare Street although the unobstructed slope appears to be more directly southwestward.

AREAS B and C - East Carlson Gulch and Sidehill Drainage.

Photographs and maps prepared prior to Interstate Highway construction show East Carlson Gulch water crossed the old county road in a culvert and followed the westerly side of the county road for more than 1,000 feet. FIGURE 3 is an enlargement of a part of the U.S. Geological Survey quadrangle map completed in 1964. The map illustrates this channel and may clarify the previous discussion of Area A. The Interstate Highway and Frontage Roads A_1 and A_2 have been superimposed on this illustration. Cross section surveys and maps prepared for Interstate construction also define the channel with respect to the old county road. The farm road which served the inhabitants of East Carlson Gulch followed a minor drainage course for about 500 feet and also intercepted sidehill drainage east of the farm road. The drainage area served by this water course was about 55 acres. The flow either passed over or under the county road to the ditch on the west side. A pile of bark and debris provided an obstacle to overflow of the ditch at the northeast corner of the Van-Evan log yard. The ditch was somewhat obstructed or obliterated


Gravel Pit
N
Former East Fork
Channel and Ditch
Missoula
Cem
3189
St Mary
Cem
Scott St.
Radio Tower
(KYLT)
3180
Scale: 1 Inch = 500 Feet
MISSOULA URBAN DRAINAGE
MISSOULA, MONTANA
FORMER DRAINAGE COURSE
NEAR FRONTAGE ROAD
Drawn
Checked
Approved
Date
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MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS
HELENA, MONTANA

FIGURE 3

by logs and grading of earth or debris although the moving water would apparently have to flow toward the ponding area near Shakespeare Street. Mr. Carlson, an old resident, pointed out the remains of an old rock wall about 200 feet north of Otis Street. This wall helped contain flood waters of the ponding area on a number of occasions.

The Interstate Highway and Frontage Roads introduced changes in these areas. Corrugated metal culverts, 48 inches in diameter carry the flow of East Carlson Gulch through Frontage Road A_1 and the Interstate Highway. A small wedge area of about 2 acres adjacent to the Interstate and Frontage Road A_2 is also drained by these culverts. The point of discharge of the 48 inch culvert through the Interstate is about 100 feet southwest of the former culvert. A median drain from about 1400 feet of Interstate Highway discharges about 250 feet further to the west. There was evidence of only minor wetting of the bottom of the culvert on June 14, 1967 indicating most of the water seeps away before reaching this point. The water from these two culverts follows the westerly side of the Frontage Road in a rather shallow ditch. The bark pile helps shear the flow along the Frontage Road. A median drain from about 2000 feet of Interstate Highway east of the underpass discharges to a ditch on the easterly side of the Frontage Road. This median drain flowed in March 1966, May 1967 and June 1967. Water marks within the culvert and at the entrance indicate a maximum discharge of about 0.5 cfs. This water is then joined by the flow from a 24 inch culvert. This 24 inch culvert now drains about 64 acres compared to the former drainage area of about 55 acres. The combined flow of these two culverts passes under the Frontage Road to join the East Carlson Gulch flow. There is no culvert through the access road to the Van-Evan yard. The access road acts as a partial barrier and the water would generally spread out over the log yard before moving to the ponding area near Shakespeare Street.

During the construction of the Interstate Highway the Contractor built or enlarged a pond on East Carlson Gulch in the gravel pit area north of the highway. The pond has a capacity of 1.3 acre feet between its low and high range. This storage volume and a high seepage rate when the pond level is high exerts a favorable influence which would generally more than offset the increase in discharge that could be attributed to the two median drains and the gutter drainage from about 2000 feet of the westbound Interstate.

AREA D - Sidehill Drainage

The area labelled D in FIGURE 2 is that of a short steep ravine. The drainage from this area of 28 acres is carried under the Interstate in a 24 inch culvert which discharges in the former channel about 600 feet north west of the corner of Otis and Scott Streets. The outlet of the culvert is on an alluvial fan created by previous deposits of the natural channel. Flow beyond the culvert would move southwestward and probably collect near the northeast corner of Shakespeare and Otis Streets. The photographs of March 11, 1966 and observations of June 14, 1967 indicate that little or no water reached that

corner. It can be said that no adverse effect can be attributed to the Interstate Highway treatment of drainage at this point.

AREA E - Sidehill Drainage.

The Area labelled E consists of about 50 acres. A 24 inch culvert through the Interstate carries the water to an alluvial fan about 400 feet northeast of the corner of Scott and Otis Streets. The disposition is similar to that of Area D, and no adverse effect could be assigned to the Interstate Highway.

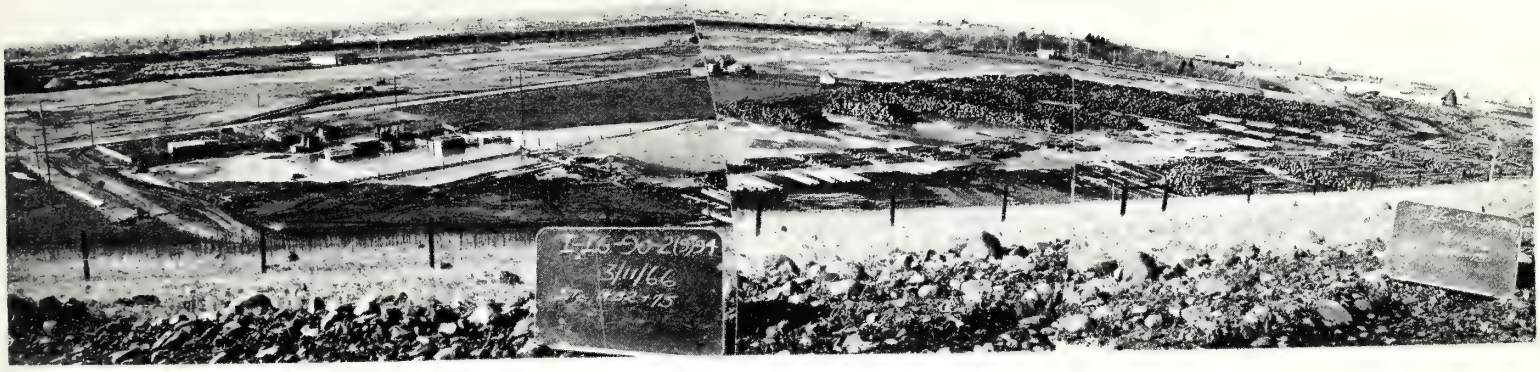
AREA F - Sidehill Drainage.

There is another culvert about 700 feet north of the corner of Clark and Holmes Streets. It receives the sidehill drainage of about 40 acres lying above the Interstate Highway (Area F) and the gutter drainage from about 1700 feet of Interstate Highway. The discharge end of the culvert is on an alluvial fan. The flow generally has been toward depressions just east of the intersection of Scott and Rogers Streets. A minor change in the channeling on the alluvial fan near the culvert could direct some flow toward Holmes Street and the west side of the older St. Mary's Cemetery. The roadway drainage represents an addition to the previous flow in this water course. There was no evidence of prior appreciable flow noted on culvert inspections of May 4 and June 14, 1967. On the latter date, it was evident the bottom of the culvert had not been wetted to a depth of more than 2 inches by rains of the previous 10 days.

1.05 RUNOFF STUDIES:

Inquiry of old residents points to more frequent flooding due to snow melt than to rain. The snow-melt flooding of March 9-11, 1966 provides some data for study of an event following Interstate construction. The panoramic photographs of FIGURE 4 present a view of the problem area on March 11, 1966 as well as on June 14, 1967. Temperatures at Missoula were substantially above normal and precipitation was slightly above normal for the period November 1965 through February 1966. A tabulation of weather data at the Missoula airport and at Missoula 2 NW (Sugar Factory) are given in the table that follows:

	Missoula Airport			
	Temperature		Precipitation	
Month	Average	Departure	Total	Departure
November 1965	36.4° F.	+ 5.9°	1.05"	+ 0.15"
December 1965	27.2°	+ 3.7°	.43"	- .65"
January 1966	26.3°	+ 7.1°	1.44"	+ .52"
February 1966	26.5°	+ 1.5°	.96"	+ .09"
March 1966	35.3°	+ 1.6°	.86"	+ 0.13"



4A- PANORAMIC VIEW OF MARCH 11, 1966

4B - PANORAMIC VIEW OF JUNE 14, 1967

	Missoula 2 NW			
	Temperature		Precipitation	
Month	Average	Departure	Total	Departure
November 1965	37.2° F.	+ 3.8°	0.79"	- 0.14"
December 1965	28.7°	+ 1.9°	.24"	- .88"
January 1966	27.8°	+ 5.4°	1.60"	+ .71"
February 1966	28.9°	+ 1.4°	.86"	+ .12"
March 1966	36.4°	+ 0.4°	.88"	+ .23"

It is necessary to use weather data from the airport station to learn how temperature and precipitation vary during the day. The temperature at 3 hour intervals, hourly precipitation and daily reports of snow on the ground are shown in graph form in FIGURE 5, for the period March 6-11, 1966. There was 3 inches of snow on the ground on March 6. The rain which began at about 9 P.M. on March 6 continued to about 9 A.M. on March 7. The concurrent wet-bulb temperatures (not shown on the graph) varied from 32° to 33° F. indicating the precipitation at this elevation was on the verge of being snow. The ground would still have been frozen in most areas. According to some residents the rain resulted in an icy glaze where the ground was bare and retention of the precipitation where snow cover prevailed. Melt on March 7 was probably minor. Sustained melt would have begun about noon on March 8 and would have continued through March 10, as temperatures remained well above freezing. Winds of about 10 to 13 miles per hour prevailed for about the last half day of this warm period to aid in the melt. The reported frozen nature of the ground during the rain could have caused an icing of a few inches of ground and very little penetration of melt water. Peak runoff from the hillsides occurred on March 10 and the below-freezing weather of the night of March 10-11 served to greatly reduce further melt.

Photographs taken on March 11 show small patches of snow on slopes facing other than south below about 3400 foot elevation. South slopes were bare of snow beyond the 3400 foot level. Complete snow cover is apparent in the higher levels of the Carlson Gulch area. Nearly all the snow was gone from about 100 acres of the East Fork of Carlson Gulch drainage and on about 90 acres of the West Fork of Carlson Gulch. From an empirical formula of snow melt with respect to temperatures above 32° F., the melt of about $1\frac{1}{2}$ to 2 inches water seems reasonable for much of the bared area. Partial melt is apparent to an elevation of about 3600 feet. Very little runoff was likely above the 3600 foot level as the snow would have absorbed some and the ground would probably not have been frozen. Conversion of the assumed melt to runoff would result in approximate value of about 20 acre-feet for the drainage area of East Carlson Gulch, the sidehill and the Interstate roadway drainage that would have reached the northeast approach road to the Van-Evan log yard.

The various culverts and channels were examined to obtain some information on peak flow at various points. There were sufficient flood marks to arrive at some approximations. The 48" culvert passing under the Interstate may have had a peak flow of about 6 cubic feet per second (cfs) at its down-

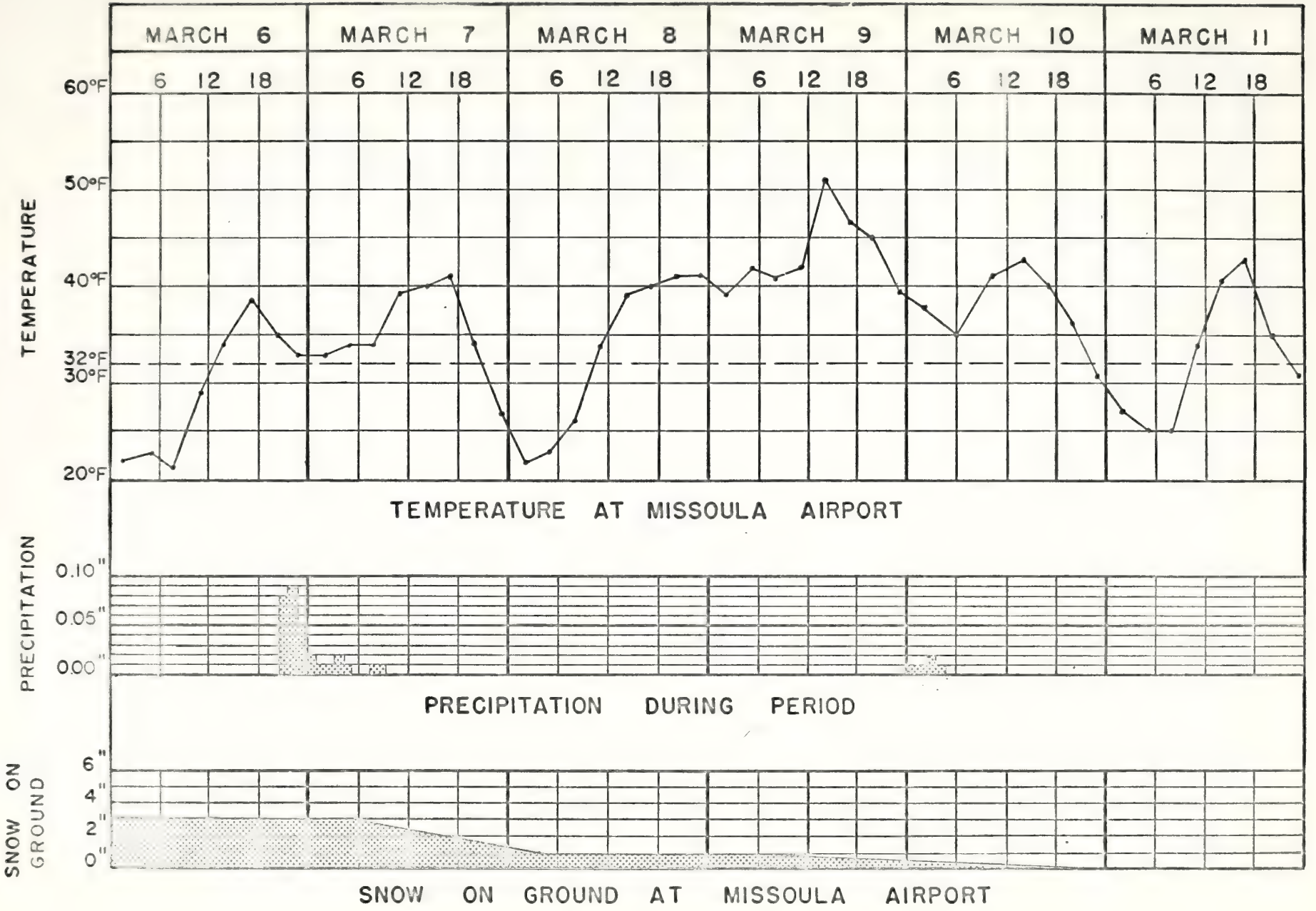


FIGURE 5

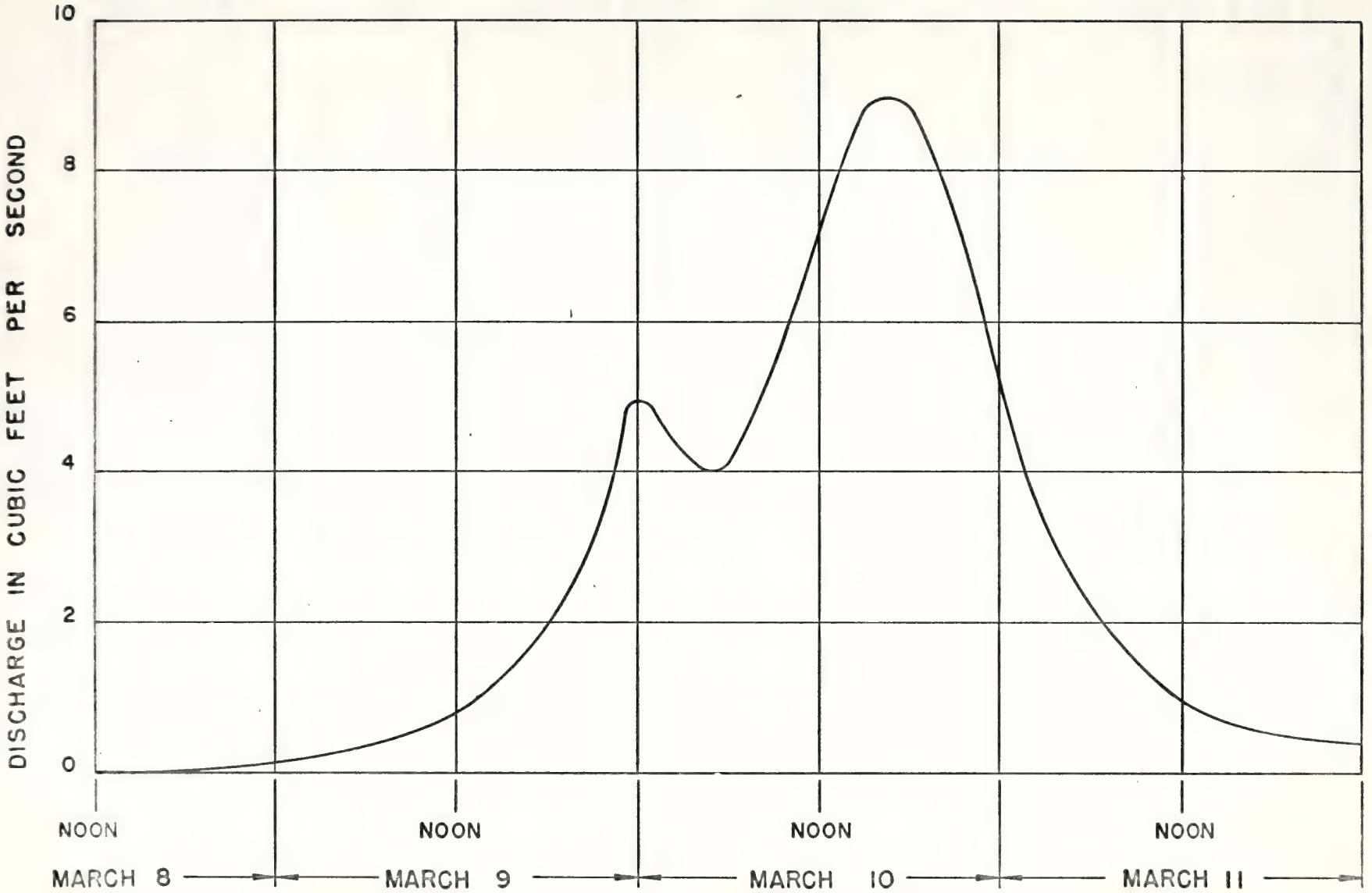
WEATHER DATA OF MARCH 6-11, 1966

stream end. A photograph of March 11 shows a flow of about 0.5 cfs. The pond on East Carlson Gulch would have exerted a little levelling influence by storing about 1.3 acre feet of water and permitting some percolation to groundwater. The scour of the earthen spillway was probably not sufficient to have caused a significant increase in flow during the latter part of the runoff period. The combination of flow from the two median drains and a sidehill and gutter drain with the East Carlson Gulch flow may have resulted in a peak flow of about 9 cfs at a point near the northeast corner of the Van-Evan log yard and the frontage road. The hydrograph FIGURE 6 depicts that flow.

In addition to that flow, the discharge of West Carlson Gulch would have reached the Van-Evan log yard at a little farther to the west. Marks in the culvert and examination of the channel upstream point to a peak flow of about 5 cfs. The volume was probably less than 10 acre-feet.

The combined flow from these areas would have reached the Van-Evan log yard. Some would have moved westward along the north edge of the Van-Evan property, some would have entered the ground and the remainder passed to the south and east to have formed a pond west of Shakespeare Street and north of Otis Street. The photographs of about noon on March 11, 1966, by Montana Highway Commission personnel provide a good record of the ponding and flows. The pond near Shakespeare Street contained about 6 acre feet of water. The remainder apparently ponded on the Van-Evan property, discharged in various directions or percolated into the soil. The natural limits and capacity of the major pond have been reduced by land fill of the log yard. The two elderly Carlson brothers who have lived along Carlson Gulch, say a low rock wall, parts of which still remain, served to limit the southeast edge of the pond near the dwelling.

Past weather records and newspaper reports were examined in an effort to enlarge the knowledge of the runoff behavior. There were periods in February 1954, January 1959, December 1964 and February 1965 that would have been conducive to high runoff from snow melt or a combination of snow melt and rain. Newspaper accounts and pictures mention and show pictures of flooding in other parts of Missoula adjacent to the surrounding hills. The lack of notice of flooding in the study area may be due to the relative effect upon the population rather than the absence of flooding that could have exceeded the events of March 9-11, 1966. Mr. Richard Ostegren and the two Carlson brothers, who have resided in the area for many years, could not recall in an off-hand way any specific dates of flooding although they recalled far greater runoff and ponding than occurred in 1966. The Carlson brothers recalled a flood of many years ago following a cloudburst. The high flow washed away a haystack near the normal banks of West Carlson Gulch, which would indicate peak flows far greater than those of 1966.



DERIVED HYDROGRAPH - MARCH 8-11, 1967

FIGURE 6

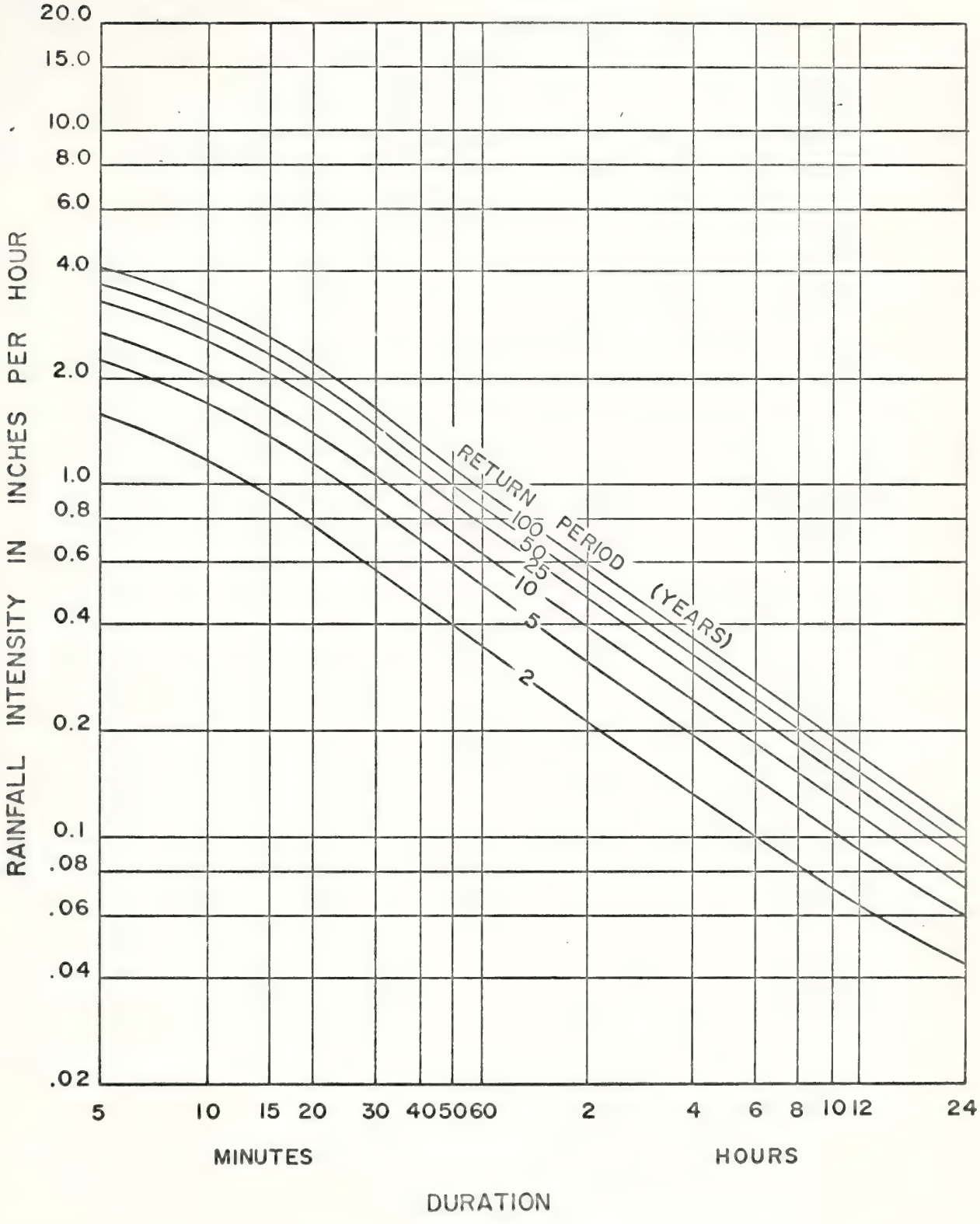
Rain alone has apparently been responsible for few floods although it can result in rather frequent interference with an operation such as the handling of logs at the Van-Evan yard. Observations of May 1-3, 1967 and June 14, 1967 show a distinct problem of poor drainage and ponding in that area. The first period included the last two days of a rainy period of a week. The total rain was 1.06 inches at the Missoula Airport. On the morning of May 2, there was evidence of night time flow from the Interstate median drain just east of the underpass. There had also been a little water in the 24 inch culvert about 400 feet east. A little water from these sources had flowed into the Van-Evan log yard. Much of the log yard was covered with a soupy clay mud.

Recorded precipitation from May 31 to June 13, 1967, was 3.01 inches. Daily amounts varied from a trace to 0.41 inch, with 0.36 inch on June 13. On June 14, there was evidence of recent peak flow of about 0.3 cfs in the Interstate median drain on the east side of the underpass and about 0.5 cfs in the 24 inch culvert about 400 feet eastward. The peak flow of the median drain west of the underpass was probably not as much as 0.2 cfs. There had been a little wetting of the upper end of the 48 inch culvert through the Interstate due to East Carlson Gulch. The water level in the pond on Carlson Gulch was 0.45 feet higher than on May 2. Recent water marks were about 0.5 foot higher than the June 14 level observed. This would indicate the temporary storage of about 0.25 acre feet. The drop of 0.5 foot confirms reports of Mr. Carlson that there is fairly rapid seepage from the pond above a fairly fixed low-water level.

The maximum recorded 12 or 24 hour precipitation at the weather station Missoula 2 NW (Sugar Factory) during the period to 1945 was 2.32 inches on November 4-5, 1927. The maximum 2 hour rain was 0.97 inch on June 21, 1938. The precipitation data for 1936 to 1952 was the basis for the intensity-duration graph of the Weather Bureau. It is reproduced as FIGURE 7. There is no available data on the probability of a continued warm winter period such as was experienced March 8-10, 1966. The unknown probability of an icy upper soil layer immediately prior to a continued warm winter period further complicates any predictions of situations similar to those of March 1966. It does seem safe to assume that winter snow-melt runoff of the approximate magnitude of the March 1966 event is not rare. Greater runoff apparently has occurred and may be expected to reoccur. The data of FIGURE 7 indicates a serious problem from rain alone may have a lesser expectancy, but should not be overlooked.

1.06 DISPOSAL OF SURFACE WATER:

The map P-11 provides detail topography for the approximate evaluation of the present pond and ponding potentials. The present pond on East Carlson Gulch exerts a favorable influence on peak flow and the volume of runoff. The effect is greater than increases in flow that could be attributed to the Interstate Highway. There was erosion of the spillway, probably in March 1966. The gravel which has since been placed in the spillway channel is not a satisfactory repair. A rebuilt spillway should be capable of discharging 50 cfs with freeboard to spare. That amount is an



RAINFALL INTENSITY – DURATION – FREQUENCY CURVE

MISSOULA, MONTANA 2 WNW

1936 – 1952

FIGURE 7

approximation of a probable 50 year flood in the upstream drainage. The spillway should be wide and have a rough surface to keep velocities as low as practical. This could be accomplished with rock rubble masonry or a series of riffles in a concrete spillway. The slopes of the dam are steeper than is generally considered good practice, although there is no evidence of sloughing or leakage through the dam. To avoid the possibility of dam failure, it is suggested that about 1500 cubic yards of gravelly material be added to the downstream side of the dam. This would result in about a 3:1 slope.

The gravel pit area just downstream and westward offers a possibility of storage, desilting and perhaps some seepage to groundwater sources. A storage capacity of about 4.5 acre-feet could be developed by the erection of an earthen dike of about 1800 cubic yards across the southwest part at dam site A. The material for the dike is available in the gravel pit area. An elevation of 3272 and freeboard of 3 feet are suggested. It would be necessary to channel the flow from an improved spillway of the present pond on a low gradient to reach this storage area. Water in excess of the capacity of this storage area should discharge back to East Carlson Gulch channel in a prepared channel. It appears best to return this water as far upstream as reasonable grades permit. This would lessen the need for erosion protection and take advantage of the favorable seepage characteristics of the broad area where the present channel meanders to the culvert through the Frontage Road. It is estimated that development of this additional ponding area could be accomplished in a safe manner for about $6,000. Most of the area of this pond would have the extremely low percolation characteristics shown by test hole No. 1. There could be appreciable percolation near the northerly and westerly boundaries.

The cost of constructing two low dams at dam sites B and C to utilize about 1.3 acre-feet of storage in each would be about $8,000. The high percolation rate shown at test hole No. 2 and the absence of groundwater in the test drill holes at the underpass give a favorable view to these two ponding areas. Some advantage of the favorable seepage characteristics could be achieved without dams by excavating a broader meandering channel through this area or by a series of cross trenches to spread the water.

The ponding area occupied by flood waters in March 1966, may currently have a capacity of about 6 acre feet without overflow over Shakespeare Street near Otis Street. It appears desirable to retain this area for storage of water which will reach this area when very substantial runoff occurs from Areas A to C and the two median drains. This ponding area would serve a useful purpose even though storage on East Carlson Gulch is developed.

PART 2

CONCLUSIONS AND RECOMMENDATIONS

The study or problem area has experienced flooding of various magnitudes through the years, principally during periods of rapid and sustained snow melt. The expanding utilization of this area for industrial and other purposes has obstructed and eliminated some of the water courses and natural ponding areas. The construction of Interstate Highway 90 and the related frontage roads A_1 and A_2 has altered the drainage conditions in the general area of the frontage road underpass to a small degree. No appreciable adverse effect was noted east of the northward projection of Shakespeare Street. The storage provided by the present pond on East Carlson Gulch has exerted a greater reduction in runoff volume than increases which might be attributed to the Interstate Highway construction. The creation of this pond and its benefits may not be assignable to the Montana Highway Commission. The rapid failure of this pond could endanger the Frontage Roads as well as aggravate the flooding problem beyond. The creation of an additional pond such as the one labelled Pond A would be a distinct improvement. The benefits of the additional pond alone would more than offset the unfavorable effects of the Interstate Highway construction through this area. The desilting that would occur in these ponds would have a very beneficial effect on downstream infiltration and percolation. Increasing the present capacity of the ditch along the westerly side of Frontage Road A, would restore the drainage pattern prevailing immediately prior to the construction of the Interstate Highway. Direct connection of such a ditch to the pond near Shakespeare Street would have some advantages. Additional ponding in depression areas which still exist could be arranged to the extent that presently developed areas would rarely be flooded. The drainage problem of this area will not be wholly solved until an adequate channel to some well entrenched stream, such as the Clark Fork, is constructed. This study has been directed to the cause and corrective measures of adverse drainage conditions arising from Interstate Highway construction. It does not attempt to do more than suggest measures which would result in additional improvement.

It is recommended the Montana Highway Commission take early steps to improve the dam and spillway at the present pond on East Carlson Gulch to avoid damage to the Frontage Road and perhaps the Interstate Highway.

Study the beneficial effect of the additional ponding area designated as Pond A. If considered advisable to undertake that construction, the improvements of the upstream dam should be arranged to be in accord.

Construct a well defined ditch of adequate capacity to replace as near as possible the former entrenched drainage course near the northeast side of the Van-Evan log yard unless the land owners concerned absolve the Montana Highway Commission of that responsibility.